

## APS Internal Assessment of the SPX Project

The APS recently suspended activity on a project that had become known as the Fast Track SPX (FTSPX) project. A program to develop a picosecond scale x-ray source was initiated in 2006 as part of the APS Upgrade program in order to provide a tool for picosecond science for the time-resolved user community. The FTSPX was an R&D project with an aggressive timeline to provide a “fast and cheap” interim picosecond source with limited capability in order to start building the user community. (A white paper had already been submitted to DOE for project funds to develop a more expensive full-performance system.) A primary consideration in setting the aggressive timeline for SPX was a desire to perform the first user experiments before LCLS turn-on in 2008. APS Management and the project team alike recognized that there were technical risks, but it was considered that the risks were worth taking because of the potential pay-off from delivering the source quickly.

As project R&D progressed, it became increasingly clear that the project would be significantly more expensive and take much longer than originally anticipated. Following a re-baseline of the project schedule and budget in October 2007, APS Management called a meeting with SPX project leadership at which it was decided to terminate FTSPX. Concurrently, this assessment of what occurred was requested by APS management. It is noted that, although the FTSPX has been terminated, benefit has come from the effort. The APS has developed the capability for strongly coupled cavity RF, thermal, and mechanical design & modeling. Development programs have also been initiated on digital low-level RF control and precision timing distribution. All these will reap benefit in future developments for the APS upgrade and in the case of the precision timing distribution, there could be significant benefit to the APS users well in advance of the APS upgrade.

### Summary of Events:

In late summer, 2004 an APS strategic planning meeting was held at Lake Geneva. At this meeting the workshop, "Time Domain Science Using X-ray Techniques" introduced a conceptual approach (attributed to Alexander Zholents of LBL) of generating short X-ray pulses at the APS. The scheme uses an rf deflecting cavity to impose a correlation (chirp) between the longitudinal position of the electron within the bunch and the vertical position/angle. A downstream cavity is needed to remove this chirp. Either bunch slicing or x-ray optics can then be used to produce the short X-ray pulse. This concept excited both the user and the accelerator communities, and considerable activity followed during the fall and winter. A white paper was written and sent to DOE in April of 2005 making the scientific case for the development of this capability and projecting a cost of \$15-\$20M for both the accelerator and beamline upgrades, and a time line that ranged from 18 to 36 months after funding. At this time the implementation focused on a CW capability using SRF cavities. The subject continued to receive attention, and a one day workshop on the development and use of this capability was scheduled for May 6, 2005, appended to the APS users meeting. Just prior to this meeting an APS user wrote a lengthy e-mail to APS management urging rapid deployment of the capability by taking what was

claimed to be an inexpensive and quick approach using normal conducting rf. This, no doubt contributed to the claim made in one of the talks that the normal conducting rf approach (relative to the SRF implementation) would have a “short development time” and be “much cheaper”.

With this push from the community, APS management called a special meeting to decide which approach to take. This was held on August 12, 2005. The merits, technical challenges, costs and schedules of both approaches were presented. The outcome of this meeting is not documented, but the decisions made are evidently reflected in the funding granted to two project proposals, one which was submitted for SRF R&D and one for normal conducting rf R&D. The SRF received full requested funding, and the normal received about half of the requested funds. Thus we proceeded into FY2006 still concentrating on the SRF option.

In June, 2006 while preparing for the APS Upgrade Summary Workshop in August of 2006, APS management began to press the beamlines for a location to locate the SRF cavities. The issue is that the SRF option requires real estate in a second ID straight section. Meetings were held to establish these plans, but sectors adjacent to sector 7 (which had been identified as the beamline which would use the short X-ray pulses) were reluctant to give up space in their straight sections. During these discussions, the possibility was introduced of implementing a pulsed source in a single sector, taking advantage of an existing preliminary design for normal conducting crab cavities from SLAC, and utilizing an unused RF klystron and modulator from the APS linac. The proposal was well received by XSD and the user representatives.

It was at this time (July 31, 2006) that the above proposal was brought to the weekly Upgrade Meeting, namely to implement the project in a single straight section using normal conducting rf cavities. This was coupled to the previously made statements that this could be done quickly (the meeting notes indicate that a completion in 2007 was suggested). Evidently we felt compelled to make a decision quickly and present our answer at the APS Upgrade Summary Workshop on August 11. George Srajer was nominated to give the talk, in which he revealed the decision; we would pursue the normal conducting implementation, it would be a one sector implementation in sector 7. It would not preclude future upgrades to multi sector or CW implementations.

The project became known as the “fast track” implementation. Portions of the above text are included to show what the interviewees conveyed... namely that through the project phase “inexpensive” was assumed and schedule became everything.

It should be noted that the ASD technical staff fully understood this to be an R&D oriented project. The worldwide experience with normal conducting s-band cavities is extensive but they had never been installed in a circular (i.e, many passes of the beam) machine with all of the associated issues of high average power, and parasitic mode rejection. Thus these were the first technical issues addressed.

An analysis was performed by the rf group as to the best place to locate the rf hardware. A total of nine options were considered. In the process of this it was determined that an external building was the best choice; in any case it would be needed for the ultimate CW solution. (After discussion the building was sized for the CW implementation.).

Meanwhile, cavity design was being addressed and found to be increasingly challenging. By March 2007, factors related to cavity design had rendered the one sector solution untenable, and compromised the performance with respect to pulse length. In early March, the SPX project team initiated discussions with XSD Management to explore the possibilities of implementing the two-sector solution (S6 and S7). Guidance from XSD was that the pulse length would need to be less than 4-5ps. The one-sector solution appeared to be marginal at achieving that, with the two-sector solution promising less than 2ps. APS management held a status meeting on April 3, 2007 where both the one- and two-sector solutions were discussed. As a result of the meeting the baseline was changed to a two sector implementation (sector six was transitioning to an XOR beamline, so the APS had more say in the use of the straight section, and dedicating 1 meter of the straight was viewed as acceptable) and the location for the building was moved to a point between the straights of sectors 6 and 7. A funding profile was generated based on information provided by the project. At this point (May 2007) the decision was made to go ahead with the construction of the building. It was understood that the building was on the critical path and would need to be started to meet the schedule.

By August of 2007 cavity design had reached the point where an external design review could be held. The review report was positive and with a short “punch list”, recommended proceeding to final design. However, by this time it was realized that all of the advances made in cavity design including heat removal, thermal stabilization, and mode damping had increased the cost of the project well beyond the requested funding.

The project suffered from ‘budget creep.’ The project was initially budgeted on the basis that the RF klystron would come from linac avoiding the need to purchase a new klystron spares (at least in the first phase). Similarly, it was assumed that the SPX system would be installed in the experiment hall. Several months into the project, it was decided that a new klystron should indeed be purchased and it was concluded that the system would be better housed in a new separate building. Both decisions were made on the basis of good technical judgment and with the agreement of APS Management. However, they increased the first-phase project cost by over \$1M from the initial budget. Furthermore, the re-baselining that came from these and other changes were communicated informally and via email, namely they were not formally documented so that the budget history could be easily tracked and reconstructed.

Had the aggressive schedule not been so central to the project planning, it might have been appropriate to manage the SPX project in two separate phases: an R&D phase to develop the crab cavities, and a project implementation phase with the decision to go ahead with implementation based on the outcome of the R&D phase.

Lessons learned / corrective actions:

- 1.) Decision making lacked documentation. The ALD office is taking action to correct this. Decisions are being documented both in Operations Directorate meetings, in the Renewal/Upgrade meetings and in Division Directors meetings.
- 2.) Rigorously define R&D projects as opposed to construction projects, and be very intentional when transitioning from the former to the latter. It is noted that at the UofC review of the APS in April of 2007, the review committee stressed the R&D nature of this project.
- 3.) Project proposals often don't capture all costs, and certainly don't allow for the requestors to include contingency. It is not always clear from the proposals what the cost and schedule risks are. For many small projects this may not be necessary, but for larger R&D oriented projects, this should be required input. This point has several components:
  - Projects requiring significant R&D should be noted as such, and receive higher levels of scrutiny, regardless of their overall estimated cost. However, it was noted by many that APS Management must strike a balance between encouraging and supporting R&D activities with technical risk (knowing they could fail) and ensuring that funds are effectively utilized.
  - Criteria based on overall cost, risk or impact should be utilized in determining the project reporting level based on a graded approach. APS management together should define these criteria.
- 4.) APS Management has not required that APS project status reports include an "estimate to complete" or "estimate at complete". Also not included in reports are schedule evaluations. Reports tend to simply note what had been done to date. A form will be provided for project status reports, and utilized in projects as determined by the criteria developed in point 2.